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UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 C.F.R. § 1.53(b))

Attorney Docket No.	
First Inventor or Application Identifier	McCUTCHEN
Title	ROTATING SCAN CAMERA
Express Mail Label No.	EK267673636US

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

1. [✓] * Fee Transmittal Form *(e.g., PTO/SB/17)* *(Submit an original and a duplicate for fee processing)*
2. [✓] Specification [Total Pages 47] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. [✓] Drawing(s) *(35 U.S.C. 113)* [Total Sheets 11]
4. Oath or Declaration [Total Pages]
   a. [✓] Newly executed (original or copy)
   b. [ ] Copy from a prior application (37 C.F.R. § 1.63(d)) *(for continuation/divisional with Box 16 completed)*
      i. [ ] DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 C.F.R. §§ 1.63(d)(2) and 1.33(b).

NOTE FOR ITEMS 1 & 13: IN ORDER TO BE ENTITLED TO PAY SMALL ENTITY FEES, A SMALL ENTITY STATEMENT IS REQUIRED (37 C.F.R. § 1.27), EXCEPT IF ONE FILED IN A PRIOR APPLICATION IS RELIED UPON (37 C.F.R. § 1.28).

5. [ ] Microfiche Computer Program *(Appendix)*
6. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   a. [ ] Computer Readable Copy
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   c. [ ] Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

7. [ ] Assignment Papers (cover sheet & document(s))
8. [ ] 37 C.F.R.§3.73(b) Statement *(when there is an assignee)* [ ] Power of Attorney
9. [ ] English Translation Document *(if applicable)*
10. [ ] Information Disclosure Statement (IDS)/PTO-1449 [ ] Copies of IDS Citations
11. [ ] Preliminary Amendment
12. [✓] Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
13. [✓] * Small Entity Statement(s) *(PTO/SB/09-12)* [ ] Statement filed in prior application, Status still proper and desired
14. [ ] Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
15. [ ] Other: .....

16. **If a CONTINUING APPLICATION,** *check appropriate box, and supply the requisite information below and in a preliminary amendment:*
    [ ] Continuation [ ] Divisional [ ] Continuation-in-part (CIP) of prior application No: ____/____
    Prior application information: Examiner _____ *Group / Art Unit:* _____
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17. CORRESPONDENCE ADDRESS

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STATEMENT CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) & 1.27(b))--INDEPENDENT INVENTOR

Docket Number (Optional)

Applicant, Patentee, or Identifier: DAVID McCUTCHEN

Application or Patent No.: _____

Filed or Issued: _____

Title: ROTATING SCAN CAMERA

As a below named inventor, I hereby state that I qualify as an independent inventor as defined in 37 CFR 1.9(c) for purposes of paying reduced fees to the Patent and Trademark Office described in:

- ☐ the specification filed herewith with title as listed above.
- ☑ the application identified above.
- ☐ the patent identified above.

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Each person, concern, or organization to which I have assigned, granted, conveyed, or licensed or am under an obligation under contract or law to assign, grant, convey, or license any rights in the invention is listed below:

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Separate statements are required from each named person, concern, or organization having rights to the invention stating their status as small entities. (37 CFR 1.27)

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small entity is no longer appropriate. (37 CFR 1.28(b))

DAVID McCUTCHEN		
NAME OF INVENTOR	NAME OF INVENTOR	NAME OF INVENTOR
David McCutchen		
Signature of inventor	Signature of inventor	Signature of inventor
Feb. 17, 2000		
Date	Date	Date

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February 17, 2000

United States Patent Application

For

ROTATING SCAN CAMERA

Express Mail Label No. EL 524 125 125 US

BACKGROUND- FIELD OF THE INVENTION

This invention generally relates to a panoramic image reproduction system, and in particular to the use of rotary scanning elements in a camera design. This invention also relates to the use of aerodynamic elements to reduce the apparent weight and provide other benefits to a rotating apparatus, and to the use of gyroscopic stabilization of a camera platform.

DESCRIPTION OF THE PRIOR ART

Cameras for capturing still or motion pictures of the external world have usually used an area array sensor, such as a 640x480 Charge-Coupled Device (CCD) for NTSC video images. These area sensors use a rectangular or square area of light-sensitive elements

and expose them all at once. New forms of Complementary Metal Oxide Semiconductor (CMOS) sensors for cameras are also being made in a variety of resolutions.

Linear scan sensors are also being used to increase resolution for specific applications. These sensors have a single row of sensors, designed for monochrome or color readout, and sensitive to either visible light or some other part of the spectrum such as infrared or ultraviolet. The image is made by successive readouts of the sensor as it moves across the image, building up the final resolution. This is also sometime referred to as a slit scan or line scan sensor. Digital scans of this type are already found in such devices as fax machines and flatbed scanners. Line scan cameras are often used in industrial processes to obtain clear pictures of objects in motion. Examples of these cameras are the Wintriss Engineering OPSIS 5150ALC for monochrome images, which uses a monochrome CCD linear sensor with 5150 pixels and onboard image processing, and the DALSA CT-E4-2048W, which uses a color CCD linear sensor with 2048 pixels. Typically these cameras are fixed in place, and look at objects moving past them. Unlike area-scan sensors, the resulting images do not suffer from motion blur.

Scan-back digital cameras, such as the Better Light Model 8000 camera back are also doing high-quality digital still photography. The use of a slow scan from a linear sensor allows for maximum resolution to be built up when photographing artwork, documents or other subjects.

Scanning sensors are also used in so-called "push-broom" satellite surveillance applications, where as the satellite sweeps across the surface, a succession of readouts of the scanner creates a very large and detailed overall image. Existing panoramic slit scan cameras have also been made that use a moving slit to expose a strip of film, such as the Widelux™ camera for stills.

Various patents describe scanning cameras. All typically feature a rotation of the scanner to create the image according to an optical axis radial to the axis of rotation. Keller's "Panoramic Camera" (US Patent 5659804), for example, describes rotation of a scanner where the nodal point of the optics for the scanner is located radially according to the axis of rotation. Oxaal's "Method and Apparatus for Producing a 360° Spherical Visual Data Set" (US Patent 5903782) also involves a radial optical axis, this time for a "fisheye" lens. Jehle's "360 degree IR Surveillance with Panoramic Display" (US Patent 4977323) uses an infrared scanner also aligned radially to the axis of rotation. Federau's "Line-Scan Panoramic Camera" (UP Patent 4532544) also describes a radial axis for a television camera. And Globus et al's "Panoramic Camera" (US Patent 4241985), marketed as the Globuscope™, employs a slit and a radial optical axis to expose a film strip. Other film strip-based scanning cameras have also been made, going back to the cumbersome Cirkut camera of the nineteenth century. Contemporary examples include the Widelux, which exposes a film strip in 120-degree increments of rotation, and the Hulcherama camera which exposes a continuous strip of film in any amount of rotation,

using gear motors to advance the film in time with the sweep of the lens. Woltz's "Panoramic Motion Picture Camera and Method" (US Patent 4602857) describes a rotating motion picture film camera. All of these cameras share the same orientation of the optical axis as being radial to the axis of rotation.

What these solutions lack is an effective way to record not only the appearance of the real world in motion through the slit, but also to use that information to create a stereoscopic image of the entire field of view. Without that stereoscopic information, the most realistic picture of a surrounding scene is not possible, as well as other applications such as rangefinding that depend on parallax offsets between different points of view. The reason for this is that existing rotary solutions assume an optical axis for the light path that is radial to the axis of the rotating array. This restriction precludes the use of other axes in a rotating array for stereoscopic effects or increased resolution. If one attempted to create a stereoscopic view with two panoramic scans taken with such cameras, by taking them from two laterally offset points in space, the stereo illusion would be strong only for the area directly orthogonal to the axis connecting the two points, but would fall off to zero as you approached that axis in the course of looking around. This is described in McMillan & Bishop's "Plenoptic Modelling: An image-Based Rendering System" in SIGGRAPH 95 Conference Proceedings pp. 39-46. An overview of stereoscopic imaging systems, including relevant US and foreign patents, can be found in Michael Starks' summary article "Stereoscopic Imaging Technology" from 3DTV Corporation (http://www.3dmagic.com).

Existing designs for rotary scanning cameras also do not address other important considerations of design needed for successful use of the camera in the field. These include the noise that the camera makes, which affects whether sound can be recorded effectively together with the picture, the weight of the unit, which affects whether a camera operator can carry it, and the stability of the camera, which is important for steady, natural motion pictures when the camera moves through a scene in the course of recording.

The present invention will address all of these shortcomings in the prior art. The present application is based in part on the disclosure document no. 466771 "Rotating Scan Camera with Oblique Axis" filed Dec. 22, 1999.

OBJECTS AND ADVANTAGES OF THE INVENTION

A. It is an object of the present invention to provide a method, and an apparatus for applying that method, for stereoscopic imaging of a surrounding scene by means of separated views having equal parallax separation throughout the scene. The stereoscopic panoramic imaging method of the present invention is not limited to an optical axis radial to any axis of rotation, unlike the prior art.

B. It is also an object of the present invention to provide a method, and an apparatus for applying that method, for increasing the resolution of the recorded image by the use of interpolated and multiplexed line scan sensors. Unlike the prior art, which is directed toward single sensors and optical paths, this use of multiple sensors enables better resolution in the final image and the use of sensors that would otherwise be unable to give good results in a single scan.

C. It is also the object of the present invention to provide a method, and an apparatus for applying that method, for recording panoramic images in full motion, by means of a simplified recording mechanism. The prior art is largely directed toward the production of panoramic still photographs, and the art featuring film-based recording in particular is unsuitable for motion picture photography, because of the need to put a large and heavy film transport and storage mechanism into rapid motion.

D. It is also an object of the present invention to provide means for recording a fully spherical field of view in a seamless manner. The prior art for panoramic scanning is primarily directed toward a cylindrical panoramic format that omits a substantial portion of the surrounding scene. Spherical imaging to date has involved multiple views that must be seamed together prior to viewing.

E. It is also an object of the invention to reduce drag and noise due to the movement of lenses. Streamlined front lens elements are unknown to prior art.

F. It is also an object of this invention to improve the stability of a camera by using rotation. The advantage of the present invention over the SteadiCam approach is the elimination of external gyroscopes, a lighter apparent weight due to aerodynamic lift, and greater axial stability due to higher angular momentum relative to the overall weight of the camera.

G. It is also an object of the invention to dynamically adjust the convergence of a panoramic stereoscopic view in order to to focus viewing on objects at selected distances. No prior art addresses this problem.

H. It is also an object of the present invention to provide a convenient and cost-effective method and apparatus for recording high-quality scan image data on film. No prior art has been able to accomplish this.

I. It is also an object of the present invention to enable smooth and balanced operation of a rapidly rotating camera using internal film reels. The prior art does not address the optimal arrangement for motion and stereoscopic recording.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 shows an oblique view of a preferred embodiment featuring a rotating drum, the motor and carrying handle for it, and two sensors in offset positions, showing an aperture slit for each sensor.

FIG. 2 shows a top view of the rotating drum of the preferred emodiment, showing the sensor and lens components of the subcamera assemblies, along with the optical axis arrangements characteristic of the system.

FIG. 3 shows a closeup schematic top view of the preferred embodiment using a fisheye lens with a streamlining covering for the drum surface.

FIG. 4 shows an oblique view of the camera featuring the preferred use of gyroscopic elements to improve the stability of the camera.

FIG. 5 is a top view of the camera drum in the preferred embodiment, showing the action of the spinning drum's sensors where an object in the field of view is scanned from different points of view, allowing for stereoscopic effects, with the addition of a rangefinding device as part of the scanning drum.

FIG. 6 shows an oblique view of the preferred embodiment of the rotating camera, with a hemispheric field of view for each of two sensors in a rotating camera drum with conventional fisheye lenses and streamlining elements.

FIG. 7 shows two equirectangular stereoscopic views produced by scans of the preferred full spherical field of view according to the present invention.

FIG. 8 is a schematic view showing the application of lateral distortion to portions of a recorded image to achieve stereoscopic convergence at a given distance, such as in would be produced by delays in the timing of the recording of scans.

FIG. 9 is a schematic view showing a preferred embodiment wherein lateral distortion is applied to a region of interest within the overall image to achieve stereoscopic convergence

FIG. 10 shows a block diagram of the various components of the entire system in the preferred embodiment.

FIG. 11 shows a top view of an alternate arrangement for increasing the overall resolution, here with four sensors in place in a rotating drum, spaced around its circumference.

FIG. 12 shows a schematic diagram of the adjacent recording of the scans from different sensors, using various amounts of delay for the signal from each sensor.

FIG. 13 shows a closeup schematic top view of a conventional lens for the sensor, and ways to streamline the rapidly rotating drum surface.

FIG. 14 shows an exploded oblique view of the camera showing the alternate addition of aerodynamic elements to reduce its apparent weight.

FIG. 15 shows an oblique schematic view of an alternate external film-based recorder for camera image information.

FIG. 16 shows an oblique view of an alternate embodiment of the camera drum using a film-based recording system.

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Docket No. 82356

DETAILED DESCRIPTION

A rotary scanning camera of a novel design offers improved performance in capturing a panoramic surrounding scene. One or more line-scan sensors are used in a sweeping recording of a surrounding scene. The scan can be of a partial rotation or of one or more full rotations. Unlike the prior art, these sensors each have an optical axis that does not intersect the axis of rotation.

In the preferred embodiment, a rotating drum holds two line-scan devices for scanning the appearance of a surrounding field of view from stereoscopically separated viewpoints, with each optical axis on approximately a tangent line to the cylinder. This creates a pair of offset sweeping scans that record objects in the surrounding view from one, then the other point of view, thereby creating an effective parallax separation in the recorded images. This parallax separation is the same for every point in the rotation of the drum.

FIG. 1 shows an oblique view of a rotatable scan camera according to the present invention. The camera comprises a rotatable drum 2, actuated by a motor 4. This drum has a central axis of rotation and a perimeter, which is the surface of the drum farthest from the axis of rotation. Two linear sensors, a Right-hand sensor 6 and a Left-hand sensor 10, are disposed at the circumference of the rotatable drum 2, each sensor having an aperture slit 8, 12. Each linear sensor has an associated lens through which light

passes according to a central optical axis and forms a focused image on an image plane orthogonal to the optical axis. The linear sensor's active surface is located in this image plane. Each sensor also has associated electronics for the input and output of signals. The sensor, optics and electronics form a subcamera assembly within the rotatable drum, which rotates in a direction shown by the arrow, 14, preferably clockwise as seen from above.

For recording a surrounding scene in motion, this drum should be rotating very quickly, and the scans should be as rapid as possible. A preferred embodiment for recording motion would be a 5-inch diameter drum rotating at 3600 RPM, with two sensors, with a complete scanned image produced by each sensor every rotation, for an effective frame rate per sensor of 60 frames per second. The resolution of the image is constrained only by the sensitivity of the sensor and its readout rate, and the ability of the data recorder to keep up. To achieve a pleasing level of resolution when viewing a closeup of a part of the image, as will commonly be done, then the resolution of the overall image should be as large as possible. A preferred resolution for the scanned image frame produced by each sensor would be 2,000 by 4,000 pixels, which represents the rotation of a 2,000-pixel sensor sampled 4,000 times during each rotation. If this 8 million-pixel image frame is produced 60 times per second, this means 480 million pixels produced per imager per second, times two channels, or close to a billion pixels per second. This level of resolution, together with the stereoscopic qualities of the image, represents an extremely high level of realism.

FIG. 2 shows a top view of the rotating drum 2, showing the preferred tangential optical axes 16 and 18 of the Right and Left sensors 6 and 10, and their associated lenses at 20 and 22, respectively. A sensor such as at 6 is usually wider than the aperture slit 8; this means that effectively, because of the space constraints of the interior of the drum, an optical axis 16 cannot be actually on the tangent of the drum, but must be located a short distance away. What is shown here is an optimal arrangement, with two roughly parallel axes 16, 18 with apertures located slightly forward of the tangent point 24. Other axis arrangements can be used, except for a radial axis 30 intersecting the center point 26. Examples are a convergent axis such as is shown at 34, or a divergent axis such as at 70. A true tangent axis is shown at 32.

Any interruptions to the surface of the drum when it is rapid rotation will create noise or whistling sounds as the drum rotates. This sound could draw unwanted attention to the camera itself, or interfere with any sound recording that is taking place along with the recording of the picture, as is commonplace in motion picture production. Because the rotary panoramic camera of the present invention would see so much of the surrounding view, a microphone would have to be placed very near the camera, such as in a location directly below it, in order to be invisible. This makes it even more important that the operation of the camera be silent, so as not to transmit any camera noise to this nearby microphone. To minimize surface interruptions from the subcamera lenses, streamlining elements should be used.

FIG. 3 shows the preferred embodiment of a conventional fisheye lens 38 for a sensor 6, and an especially wide streamlining front element 40 conforming to the drum surface 42 that takes into account the wide horizontal field of view characteristic of this type of lens. For a specialized line-scan lens, the lens is very narrow and flat, with an arrangement of elements like a slice taken through the middle of a conventional lens. This flat lens has the advantage of the least surface interruption, but lacks the light-gathering abilities of a more conventional round lens, which is the preferred embodiment. While a flat fisheye line-scan lens for a slit aperture, such as those produced by Coastal Optical, may have an f-number of f8, a conventional round fisheye lens could have an f-number of f2.8, for nearly eight times more light delivered to the sensor.

The rapid rotation of the camera drum required for motion picture recording creates special challenges. This rapid rotation, however, also has certain advantages. This motion can be used to increase both the stability and the portability of the camera when it is use.

FIG. 4 shows how increased stability in the camera, especially when it is carried by a camera operator, can come through the use of the gyroscopic effect. Unlike other scanning cameras, the optical and electronic elements in the present invention can be concentrated around the periphery of the drum, producing a weighted wheel 44 balanced around a central axis of rotation 46 and a relatively open center 48, which fits the design

of a classic gyroscope. The rapidly rotating drum 2 and its attached motor 4 thus form a unit that tends to maintain its position in space. The inertia of the rapidly spinning drum weight acts to maintain the wheel in its original plane and to resist attempts to turn it into other orientations. This produces a steadier camera that removes bumps and shakes from a recorded motion picture. Gyroscopically stabilized platforms are found in various fields, as well as in the Steadicam™ line of camera supports for camera operators. In the present invention, the gyroscope is integrated into the design of the camera itself. A camera operator is shown at 50, holding a handle 52 which in this case has an optional universal joint 54 at the top, to allow the rotating camera drum to float more freely in space. The slip ring connection for passing signals to and from the drum is shown at 56, and the input and output line for the camera unit is shown exiting the handle at 58.

FIG. 5 shows the action of the spinning drum's sensors in the preferred embodiment where an object in the field of view is scanned from, one, then another, point of view. Five optical axes for the spinning sensor 10 on the drum 2 are shown at 60, 62, 64, 66, and 68, and how the scans of the sensors, especially for very near objects 70, simultaneously sweep different areas 72 and 74. Thus objects are scanned at different times, from different directions. For instance, a comparable area 76 of the near object 70 is shown as being scanned by sensor 6 according to the optical axis 78 at the first position 80, but the same target area is scanned at the fourth position 66 for the sensor 10. This scanning of objects from different points of view creates the parallax separations within the image that are the basis of any stereoscopic effect. The lateral location within the

scanned image is a function of time, because it is the point in time at which the image appeared in the aperture. The scanned area on the object is shown for the Right 6 sensor at 82 and the Left 10 sensor at 84, as well of the area 86 of the object 70 where the images from the two sensors overlap.

The amount of parallax separation in the image is determined by the distance between the camera and the object being viewed. A preferred way to determine this distance is through the addition of a rangefinding element to the rotating camera drum. This rangefinder is shown as being made up of an emitter element 88 and a sensor element 90. This rangefinder, either a miniature radar or infrared-based unit, takes readings either continuously or at intervals, to determine an average distance for the objects in the surrounding field of view during the course of a rotation, and the corresponding adjustment profile recommended. This convergence profile for the rotation can be used to determine the amounts of delay to apply to the scans prior to their being recorded, or to determine a later correction for convergence in the display of the stereoscopic images.

FIG. 6 shows an oblique view of the preferred embodiment of the rotating camera, with a hemispheric field of view for each of two sensors 6 and 10 in a rotating camera drum 2 with streamlining elements such as at 40. A fisheye lens 38 with an optical axis 16 is shown for sensor 6, producing a scan 92 with a vertical field of view which extends 180 degrees. As the drum 2 rotates 14 around an axis of rotation 46, according to a motor 4, additional scans are produced, such as the second scan 94. The same is true for the scans

96 and 98 as recorded by the sensor 10. The vertical boundary of a scan's field of view is at 100. The signals from these scans, as well as any necessary input signals, pass through a slip ring connection 56 and through a connecting cable 58, shown here exiting at the base of a handle 52.

FIG. 7 shows examples of two equirectangular stereoscopic views 102 and 104 produced by scans of a full spherical field of view from two sensors in the preferred embodiment. The scene here is of a carnival midway, with a swing ride sending riders overhead. This type of image is the result of a linear fisheye sensor with a hemispheric vertical field of view being rotated through a full 360-degree rotation. The characteristic stretching of the image toward the poles is evident. The two stereoscopic views can be considered as a "left-eye view" and a "right-eye view".

For simplicity, the optical axes of the two sensors in the camera should be in the same plane and essentially parallel, facing toward the same side of the drum, for the effect of convergence on objects at infinity. By the addition of delays in one or both channels of the stereo image, the appearance of an object can be shifted in the recording or playback in either direction by adjustment of the amount of delay applied to each vertical scan before is used. The amount of adjustment for this convergence depends on the distance to the desired object.

FIG. 8 is a schematic view showing of the application of lateral distortion to portions of a recorded image to achieve stereoscopic convergence at a given distance, such as in would be produced by delays in the timing of the recording of scans. What is shown here are the timings of the recordings of the scans, relative to an uncorrected timebase of recording which proceeds from left to right within the frame of information 106. All of the scan information proceeds through a FIFO delay buffer with a certain default delay. Adding to or subtracting from this default delay allows for shifts either forward or backward in time. An uncorrected region is shown at 108. A region where the scans are shifted to the right (forward in time) is at 110, and a region where they are shifted to the left (backward in time) is at 112. One view may be affected in this way, or both may be used for a greater range of corrections.

When the final image is viewed, either as a mono or stereo image, the preferred embodiment employs the extraction of a smaller movable window of interest as needed. This presents a more natural view of a portion of the overall scene, while allowing the freedom to look around in any direction. This extraction of a region of interest can be from either a live or prerecorded image stream.

FIG. 9 is a schematic view showing of the preferred application of lateral distortion for convergence to a region of interest 114 within the overall image 106 in order to align objects atop one another. To conserve computational steps in this essentially digital process, this image transformation can be done only on the portion of the whole frame

within or immediately adjacent to the region of interest 114. An example of a portion of the scans shifted forward in time is at 116, and scans shifted backward in time are at 118.

The preferred recording device for picture information would be a digital recorder, such as a streaming tape or based digital recorder. Application of image compression to the picture information prior to use reduces the bandwidth necessary for any digital storage, transmission, or playback.

FIG. 10 shows a block diagram of the various components of the entire system in the preferred embodiment. The Right 6 and Left 10 Linear Sensors have equivalent associated components such as optics 20 and 22 and optical axes 16 and 18, respectively, forming two subcamera systems within the boundaries of the camera drum 120. Each sensor has its associated power and drive electronics 122 which are coupled to a central Power source 124 and Control electronics 126, which are realted to the motion control regulation 128 for the motor 4. The sensor outputs an electronic signal representing raw digital image data 130. This data goes through image compression 132 and any necessary I/O formatting 134. Then the image signal exits the drum through rotary Slip Rings 136. A separate rangefinder 138 on the drum outputs distance data 140 for controlling stereoscopic convergence. The image data from the sensors then is processed with the appropriate delays 142 for alignment of their scans together in time, plus any convergence adjustments. To conserve the number of recorders needed, the data from

both channels may be multiplexed together 144 prior to being sent to the recorder 146, which preferably should be digital.

During the Playback process 148, the image data can be transmitted 150 prior to decompression 152 as part of a display process featuring the extraction of a movable Region of Interest 154 which appears on a Display 156.

Alternate embodiments of the present invention are directed toward the solution on specific problems. For example, line-scan sensors at the present time do not have a fast enough readout rate to produce the above horizontal resolution if the drum spins around very rapidly. One solution to this would be to multiplex several sensors to fill in greater resolution.

FIG. 11 shows an alternative embodiment of the present invention, comprising four sensors, 10, 16, 18 and 20, in place in a rotatable drum 2. If the requirement is for 4,000 scans during one revolution, which represents one frame, and the fastest that could be read from an individual sensor is 1,000 readings per frame, then these four sensors 10, 158, 160 and 162 could be used to build up the proper resolution. Each of the four sensors has the same angle of optical axis 164, 166, 168, and 170 relative to the drum 2, according to their associated lenses at 174, 176, 178, and 180, and the four sensors are equidistantly spaced around the circumference of the drum. In operation, with the drum rotating, each sensor would scan an object in the surrounding view at a slightly different

time. By the addition of digital delays, these scans can be recorded adjacently, to produce an apparently continuous image.

FIG. 12 shows a schematic diagram of how a composite image is assembled from the data coming from the sensors, showing how sensor spacing about the circumference of the rotatable drum 2 is taken into account when recording signals from the sensors. At 182 is a scan signal from the first sensor 10, and at 184 is the signal from the second sensor 158, taken at the times when they are at roughly the same point on the rotating drum relative to the surrounding scene. By adding an appropriate amount of fixed delay 186, these scans of a given portion of the surrounding field of view are recorded adjacently at 188 and 190, respectively. Amounts of fixed delay for each sensor compensate for the time differences between when a scan took place and when it is recorded. It is preferable to have the sensor spacing be as close together as possible, to minimize any visible discontinuities due to these time differences between the adjacent scans as they are recorded in the final image.

FIG. 13 shows an alternate embodiment for streamlining and soundproofing the camera. If a clear enclosure 192 is used to encase and soundproof the spinning drum 2, then the optical axis 16 of a sensor will exit the enclosure at a very oblique angle, producing distortion as it passes through the enclosure, and any seams in the clear enclosure will appear as interruptions in the overall recorded field of view. There is also the potential

for problems from internal reflections from the enclosure surface into the lenses. Thus an enclosure is not the preferred solution to this problem.

The large front surface of a conventional lens 194 would oridinarily create an interruption on the drum surface 42 that would produce noise, but the front of the lens can be made to conform to the surface of the drum by a streamlining front element 196. An optimum design for a lens might be a hybrid, with a Gradium™ front element, where the differing refraction index characteristic of this type of glass runs laterally across the front of the lens, in a direction at a right angle to the line of the sensor. This produces a front element 196 that has the optical characteristics of a flat element, but which is thicker on one side than the other, to match the contour of the drum surface 42. The slant could be reversed for opposite sides of the drum, again to match the surface. An alternate covering would be more conventional glass for streamlining, but this has the risk of introducing optical distortion in some form.

The apparent weight of the camera when it is in operation is important to the camera operator, because the heavier the camera is, the harder it is to carry around. Here again the rapidly spinning drum of the camera can be used to advantage. Added aerodynamic lifting elements attached to the rotating drum can offset the apparent weight, making the camera more portable.

FIG. 14 shows an alternate embodiment featuring the addition of aerodynamic elements. These aerodynamic elements can be one or more of a variety of types, depending on the amount of lift required and whether they must be relatively silent so as not to create noise that would interfere with any sound recording. These elements can be located in many different places on the rotating drum 2 and still remain invisible to the sensors. Because the center 48 of the drum can be relatively open, due to the peripheral positioning of the sensors and the gyroscopic distribution of the weight, a rotor or propeller 198 can be located even in the interior of the drum, as well as above 200 or below it 202. Surface ripples 204 can also be built into the upper surface of the drum, to create a region of lower air pressure and lift when the drum is spinning. Outer rotor flanges also in the manner of propellers 206 can also be built into the outer surface of the drum, as long as they remain invisible to the sensors. All of these rotors can act to lift the camera upward, and thus reduce the apparent weight to the camera operator. The camera operator's hand should be shielded from the strong wind that these rotors would produce, and care should be given to the spinning tips of the rotors by adding guards such as at 208 if necessary to prevent them from causing injury.

A special type of element can also be used for automatically keeping the front surface of a lens clean and dry, by making use of the speed of the relative air stream past the drum surface. For the 3600 RPM example cited above, the wind speed on the outer drum surface would be almost 55 mph. A special curved scoop channel enclosure 210, located beneath the lens but still invisible to it, can continuously draw in dry air from beneath the

drum and deflect it upward, creating a strong current of air that will deflect rain and dust away from the lens surface. Here a counterclockwise rotational direction is indicated at 212, and the central axis of rotation is at 214.

For large amounts of image data, unusual recorders may be used. One applicable form of recorder is a film strip recorder. High-quality film has the advantage of offering higher density storage of image data, in an essentially analog form, at a lower cost than conventional digital streaming media, especially for large quantities of images.

FIG. 15 shows an oblique schematic view of an alternative external film-based recorder for image information from the camera. Unlike conventional panoramic cameras, the film apparatus described here is located external to the camera drum itself. The dimensions of the film strip thus need have no physical relation to the primary drum apparatus. The only communication between the two is through electrical transmission of the signals from the sensors shown here coming in on a line 216. The image is formed for the film strip recorder by means that turn the electrical signals representing the scans back into light in a linear display 218. Amplification of the signals 220 can be applied if necessary to produce the proper image, which is focused and reduced through optics 222 before it is recorded onto the continuously moving film at an exposure point 224. The supply reel for the film is at 226, and the takeup reel is at 228. Because the film strip is in constant motion, a continuous image is built up through the recording process. Any divisions in this recorded image on film, such as frame divisions, should be based on the

film sprocket holes outside the image, or other measurements of distance, and not be interruptions to the image. The image on the film can be digitized at another time if desired, such as for playback or transmission of the image.

FIG. 16 shows an oblique view of an alternate embodiment of the camera drum using a film-based recording system. The entire apparatus must rotate according to an axis of rotation 230. The supply reel 232 is in an upper portion of the drum 234, and the film 236 goes down into a middle portion 238 where it is exposed at 240 by a slit aperture according to the optical axis 16. The film proceeds down 242 to the lower portion 244 where it is wound onto the takeup reel 246. A similar arrangement of parts would have to be done for a second point of view such as for stereoscopic recording. This arrangement has the advantage of offering balance of the weight of the supply and takeup reels around a central axis of rotation 214. This allows rapid rotation without undue vibration and instability. Film as a recording medium may be chosen because certain films may be more sensitive than a digital sensor, and yield better images. However, this approach has several disadvantages. Foremost among them are the size and weight of the apparatus required, and the difficulty of putting it into rapid rotation for scanning.

OPERATION, RAMIFICATIONS AND SCOPE

Accordingly the reader will see that the rotating scan camera of this invention can be used to record a panoramic field of view with increased resolution and stereoscopic separation throughout the recorded image. In addition, the rotation of the camera drum can be used to impart stability and to lighten the apparent weight of the camera when it is in operation.

Although the description above contains many specificities, these should not be construed as limiting the scope of the invention but as merely providing illustrations of some of the presently preferred embodiments of this invention.

For example, a single oblique sensor will also produce a usable panoramic scanned image, although without the stereoscopic features of a dual scan. Lesser resolution sensors can be used for more inexpensive solutions or for situations where the bandwidth for recording or playback is limited.

The arrangement of optical axes shown here as tangential can also be created within a larger drum. In this case, the axes are still parallel and in the same plane, but the apertures are located farther forward from the tangent point. Oblique but not tangential axes can also be used, either convergent or divergent relative to the tangential axis. The

optical axes in these cases still do not intersect at any point behind their lenses and within the drum, unlike the radial axis arrangement characteristic of the prior art.

The sensors can be in monochrome, color, or having another spectral sensitivity such as Ultraviolet or Infrared. An example of a color linear sensor is the Eastman Kodak KLI-2113, a trilinear RGB sensor with a 2098x3 resolution, an image area of 29.4 x 0.24 mm, a sensitivity of 14 bits, and a readout rate of 60MHz. Other CCD and CMOS line scan sensors have other parameters. Generally speaking, at the present time, CCD sensors are more sensitive than CMOS sensors and allow for exposure of an entire vertical scan at once, but require more complex power sources. CMOS sensors, on the other hand, can incorporate many types of logic elements on the chips themselves. This enables on-chip functions such as digitizing, compression, enhancement, and pattern recognition.

Preferably the line scan sensor should be as sensitive to light as possible, as well as having a very fast readout rate. The fast readout rate enables many individual vertical scans to be read from the sensor while it is in motion, and the sensitivity of the sensor enables a usable image to be produced even during the extremely short exposure time represented by such rapid scans. PixelVision and Scientific Imaging Technologies of Beaverton, Oregon have developed especially sensitive back-illuminated CCD's for astronomical use.

If multiple sensors must be used to build up the proper resolution, then they should be carefully spaced around the periphery of the drum while taking into account the desired resolution. For example, four sensors, each limited to a readout speed of only 1000 scans during the course of a revolution, are used to build up an overall resolution of 4000 scan totoal. If the four sensors are spaced within a span of 90 degrees on the drum and exactly 22.5 degrees apart, then every 62.5 scans (1000*(22.5/360), each sensor would reach the same position as the next one in line. The first sensor, in other words, would advance in the course of the revolution, and after 62.5 scans the next in line would reach the starting position of the first. What is needed, however, is not a mere duplication of the first reading, but another reading taken slightly ahead or behind this point, to help fill in the gaps represented by the readings of a single sensor. If the intention is to fill in the gap going backward, then the spacing between the sensors is increased by a slight amount representing one increment of the desired final scan resolution, in this case 4000 scans. For a 12.7 cm (5-inch) diameter drum, which is a preferred size to use because of the amount of parallax separation it produces, the circumference is 398.98mm or almost exactly 10 scans/mm as the drum rotates. Thus the added increment of spacing for each would be approximately one-tenth of a millimeter.

Each sensor should have the same type of lens, to enable the matching of recorded images. Since the horizontal field of view of the line sensor is negligible, the important consideration for the lens is its vertical field of view. In the preferred embodiment, a fisheye lens, characterized by having a field of view of close to 180 degrees, is used to

achieve an essentially spherical recording of the surrounding view as the drum rotates. The lens should be small, of high quality, and fast, which means that it transmits light efficiently. Good quality lenses of this type are being made by Coastal Optical. Estelle's "Wide-angle Photographic Lens System and Photographic Camera" (US Patent 5502597) describes an especially compact and efficient design for a wide-angle lens. In order to ensure recording of the area directly above the rotating camera, while creating a "blind spot" directly underneath it to hide a camera operator or mount, it may be preferable in practice to construct the subcamera assembly so as to raise the axis of the lens by up to 10 degrees from the horizontal plane of the drum.

As the vertical angle of view increases, an exposure difference becomes apparent in different segments of the line sensor. For a global scan of a spherical field of view, for instance, this exposure difference comes from the different rates of speed found in scanning around the poles versus scanning at the equator. Another way to illustrate this is to observe the difference in rotational speed of a point on a globe near the poles, as compared to a point on the equator. To adjust for this, a fixed signal compensation function can be applied to the signals from different sections of the linear sensor.

The motor assembly should be very smooth and quiet, and able to hold to a precise rotational speed. Various types of electronically controlled motors have been developed to meet these characteristics. A recent line of direct-drive brushless dc motors from Thomson Airpax Mechatronics Group are 66% smaller and 30% more efficient than other

industry-standard motors. A smaller size for the motor would aid in the portability of the camera system by making it lighter in weight overall. Sinusoidal motion control is preferred for the smoothest possible regulation of speed. An 1800 RPM motor would produce an effective frame speed of 30 fps. This happens to be the type of motor used for the head drum in a VHS tape machine.

Rotary couplings such as slip rings are used to transfer electrical signals to and from the electronic elements in the rotating drum. Litton Poly-Scientific's EC3848, for example is a high speed slip ring assembly of up to 10 lines for rotational speeds up to 10,000 RPM. Examples of the type of signals that would go into the drum are power and timing signals for the sensors, while the readout from the sensors would come out along one or more lines as required. Some sensors have multi-tap readouts to increase effective resolution and data speed. The DALSA CT-E4-2048W, for example, uses the IT-PI-2048 sensor which has four simultaneous readout channels at speeds of 20Mz to 25Mz each, for an effective readout rate for the sensor of up to 100MHz. The number of rings in the coupling depends on the number of electrical channels needed to maintain proper connections.

Rangefinding sensors come in a variety of configurations. The miniature radar-on-a-chip invented at Lawrence Livermore Laboratory in 1995 is one example of a low-cost sensor that could be used to obtain readings of the distance to various objects during the course

of a scan. Active Infrared Autofocus devices such are found on still cameras could also be used, especially to give distance readings within a range of around 20 feet (6m).

For more convenient use of the image data from the sensors, compression should preferably be applied to the data prior to its transmission from the drum. Various methods for image compression are currently available, such as Discrete Cosine Transform (DCT) and the Motion Picture Experts Group (MPEG) family of motion picture compression. A preferred embodiment for compression in the present invention would be wavelet compression. The final data rate for the output would be determined by the desired level of quality in the image, as well as the optimum data rate of the recorder.

For digital readings from the sensors, a variety of data transfer protocols could be used for sending the data for external recording, transmission or processing. The transmission can be in the form of a wired or, preferably, a wireless connection. The preferred embodiment makes use of one of the new high-quality high-bandwidth standardsThese include Fibre Channel (ANSI x3.230), which is made for fiber optics and has an effective speed limit of 400 mbps (million bits per second), the same speed as for the IEEE-1394 "Firewire" interface. Serial Digital Interface (SDI; a.k.a. SMPTE 292M) has a maximum speed of 1200 mbps, and Gigabit Ethernet, 1000 mbps. The Gigabit Internet standard (GVIF) has a maximum speed of 1776 mbps. An even faster data speed is represented by 10 Gbps Ethernet standard now being developed by the 10 Gigabit Ethernet Alliance,

Ethernet Alliance, including such companies as Intel, Extreme Networks, Nortel, World Wide Packets, and other companies. This speed would handle the full-bandwidth data stream from the preferred resolution and frame speed described above as the preferred embodiment.

The image data coming from each sensor represents a vertical column. The columns are put together to make the final image. Video images, on the other hand, are made up of rows, which are read out horizontally. In order to convert one to the other, an image made up of columns is read out in rows, which can be done easily using a frame buffer and a simple processor. A readout of an HDTV video image of approximately 1920 by 1080 pixels (which can be identified as High-level, High-profile ADTV), is preferred, as a way of preserving maximum image quality within existing video standards. HDTV digital recorders such as the Panasonic AJ-HD2700 D-5 VCR (for a high-bandwidth SDI signal) or even the low-cost Panasonic PVHD 1000 D-VHS VCR (for a compressed signal) recorder are examples or recorders that could be used for this purpose.

For a film strip recorder for the image information, the image can be formed for the film by a linear diplay. Many forms of displays and microdisplays may be suitable, depending on the brightness, size and image characteristics required. These displays include an LED or laser diode array, or a linear CRT, LCD, DLP (Digital Light Processing) or plasma display, with reduction and focusing optics as necessary to transfer the light onto the film. A linear color plasma display has the advantage of apparently continuous

example, has pixels measuring 1.08 mm square; therefore a 2098 pixel linear sensor requires an array 226.584 cm (89.2 inches) long, which requires substantial reduction optics. An alternate form of arrangement would be to split the display into a multiplicity of sections, which are combined to make a continuous recorded image. This can make use of any multi-tap readouts of the sensor, such as those featured in the DALSA camera mentioned above, where each of the four parallel channels coming from the sensor can be made to control its own display array. The Cine V Solitaire Image Recorder (US Patent 4754334) is an example of an advanced film recorder for digital data.

The extracted signals from the sensors can be sent to other locations for use via electronic transmission, for either a live or a prerecorded image. It is preferred that a movable region of interest be extracted from within the overall image, either live or prerecorded. If taken from the live image, then if desired, the rest of the image can be discarded. This has the advantage of reducing the overall requirements for transmission or processing.

Thus the scope of the invention should be determined by the appended claims and their legal equivalents, rather than by the examples given.

ABSTRACT

A scanning camera with a rotating drum has one or more sensors characterized by a non-radial optical axis. With two sensors on opposite sides of the drum and facing in substantially the same direction, stereoscopic recording of a panorama is accomplished as the drum rotates. Rapid rotation of the scanning camera produces panoramic motion picture recording, with the final frame speed dependent on the sensitivity and speed of the sensor, the resolution desired, and the capabilities of the recording device. The preferred embodiment employs rotating fisheye lenses for a substantially full-sphere field of view. Streamlining of the lens elements on the drum surface is described for quiet operation of the camera, even at high rotation speeds. The rapid rotation of the drum characteristic of motion picture frame rates can improve both the stability and portability of the camera. The gyroscopic effect of the rotating weight of the drum can increase the stability of the camera, and the apparent weight of the camera can be reduced by the lifting effect of aerodynamic elements such as rotors added to the rotating drum. The adjustment of convergence are described that improve the viewing of stereoscopic images. Additional sensors in the same arrangement are used to increase resolution through multiplexed recording of the image data. Recording image information using film, either internal or external to the camera drum, is also described as a cost-effective alternative to digital media storage.

LISTED PARTS IN DRAWINGS

FIG. 1

2. Cylindrical drum

4. Motor for rotatable drum

5 Right-hand sensor

8. Aperture for Right sensor

10. Left-hand sensor for stereoscopic scan

12. Aperture for Left sensor

14. Clockwise direction of rotation

10 FIG. 2

16. Semi-tangent optical axis for Right sensor

18. Semi-tangent optical axis for Left sensor

20. Right lens

22. Left lens

15 24. Tangent point

26. Center of rotation

28. Drum surface

30. Radial axis

32. Tangential axis

20 34. Convergent axis

36. Divergent axis

FIG. 3

38. Fisheye lens

40. Wider front

42. Drum surface

FIG. 4

44. Weighted wheel

46. Axis of rotation

48. Open center

50. Camera Operator

52. Handle

54. U-joint swivel

56. Slip ring connection

58. Input and output line

FIG. 5

60. First rotary position of Left sensor

62. Second rotary position

64. Third rotary position

66. Fourth rotary position

68. Fifth rotary position

70. Near object

72. Area of first sweeping scan

74. Area of second sweeping scan

76. Target area of near object

78. Axis for first position of Right sensor

80. First position of Right sensor

82. Scanned area on object from Right sensor

84. Scanned area on object from Left sensor

86. Area of overlapping scans

88. Rangefinder emitter

90. Rangefinder sensor

FIG. 6

92. Hemispherical linear scan from right sensor

94. Second hemispherical scan from right sensor

96. Hemispherical linear scan from left sensor

98. Second hemispherical scan from left sensor

100. Vertical boundary of hemispherical FOV

FIG. 7

102. First equirectangular view

104. Second equirectangular view

FIG. 8

106. Frame of information

108. Uncorrected scans

110. Scans shifted to right (delay forward in time)

112. Scans shifted to left (delay backward in time)

FIG. 9

114. Region of Interest

116. Selected scans shifted forward in time

118. Selected scans shifted backward in time

FIG. 10

120. Boundary of Drum

122. Power and Drive for sensor

124. Central Power

126. Central Control

128. Motion Control

130. Raw digital image data

132. Image compression

134. I/O formatting

136. Slip rings

138. Rangefinder

140. Distance Data

142. Delays

144. Multiplexing

146. Recorder

148. Playback

150. Data Transmission

152. Decompression

154. Region of Interest Extraction

156. Display of ROI

FIG. 11

158. Extra interpolated sensor #2

160. Extra interpolated sensor #3

162. Extra interpolated sensor #4

164. Basic optical axis for sensor #1 (Left)

166. Extra optical axis for #2

168. Extra optical axis for #3

170. Extra optical axis for #4

172. Rotational distance between sensors 1 and 4

174. Lens for sensor #1

176. Lens for sensor #2

178. Lens for sensor #3

180. Lens for sensor #4

FIG. 12

182. Scan from #1

184. Scan from #2

186. Delay for #1

188. Recorded position for scan #1

190. Recorded position for scan #2

FIG. 13

192. Enclosure

194. Conventional lens

196. Streamlined front element for conventional lens

FIG. 14

198. Interior rotor

200. Rotor above

202. Rotor below

204. Surface ripples

206. Outer rotors

208. Rotor tip guard rail

210. Scoop Channel Enclosure

212. Clockwise rotation

214. Axis of rotation

FIG. 15

216. Transmission line for sensor information

218. Linear display

220. Amplification and processing of signal for display

222. Reduction optics

224. Film recording

226. Supply reel

228. Takeup reel

FIG. 16

230. Axis of rotation

232. Supply reel for film camera drum

234. Upper portion of drum

236. Film in upper portion

238. Middle portion of film camera drum

240. Film in lower portion

242. Exposure point

244. Lower portion of film camera drum

246. Takeup reel for film camera drum

CLAIMS

I claim:

1. A camera for recording a panoramic field of view in a scanning fashion, comprising:

i. a rotatable drum having an axis of rotation and a perimeter; and

ii. at least one subcamera disposed at the perimeter of the drum, the subcamera comprising

a lens having an optical axis and an image plane, said optical axis being not radial to said axis of rotation; and

a linear sensor having a sensor area which intersects said optical axis and which lies within the image plane.

2. The camera of claim 1, wherein the optical axis of each lens is substantially tangential to the perimeter of the drum.

3. The camera of claim 1, wherein an even number of subcameras are disposed at the perimeter of the drum.

4. The camera of claim 3, wherein the subcameras are disposed substantially on opposite sides of said drum, and provide in the course of the rotation of the drum, a repeated

viewing of objects in the surrounding environment from two points of view with parallax separation.

5. The camera of claim 1, wherein each lens has a vertical field of view of at least 160 degrees.

6. The camera of claim 1, wherein the linear sensor produces a monochrome signal.

7. The camera of claim 1, wherein the linear sensor is sensitive to infrared wavelengths.

8. The camera of claim 1, wherein the linear sensor provides a color signal.

9. The camera of claim 1, wherein means for transmission are coupled to said sensors.

10. The camera of claim 1, wherein the rotation of the rotatable drum is 360 degrees, and repeated in regular periods.

11. The camera of claim 10, wherein the rotation is at least 15 times per second.

12. The camera of claim 10, wherein the rotation is at least 30 times per second.

13. The camera of claim 10, wherein the rotation is at least 60 times per second.

14. The camera of claim 10, wherein the camera weight is balanced at the axis of rotation.

15. The camera of claim 10, additionally comprising means for aerodynamic lift.

16. The camera of claim 10, wherein the electrical readings of the linear sensor, representing pictorial information, are grouped to form images representing a portion of a rotation.

17. The camera of claim 16, wherein image compression is applied to the pictorial information.

18. The camera of claim 16, wherein processing means are used to extract a movable region of interest from the pictorial information.

19. The camera of claim 16, wherein the images each represent one complete rotation.

20. The camera of claim 16, wherein the images represent images with stereoscopic separation.

21. The camera of claim 20, wherein both stereoscopic images are viewed together as a stereo pair.

22. The camera of claim 21, wherein the convergence of the stereoscopic images is controlled by lateral distortion of one of the images relative to the other.

23. The camera of claim 22, wherein a rangefinding sensor on the drum is used to determine the amount of lateral distortion applied.

24. The camera of claim 1, further comprising recording means for the electrical signals representing the pictorial information from each subcamera.

25. The camera of claim 24, wherein said recording means include means for multiplexing said electric signals.

26. The camera of claim 24, wherein said recording means include a film recorder, and said electrical signals are first converted into light before being recorded on a strip of photographic film.

27. The camera of claim 24, wherein playback means are coupled to said recording means for subsequent playback of the pictorial information.

28. A self-cleaning camera, comprising:

i. a rotating camera with at least one lens, and

ii. at least one scoop channel enclosure with an intake and an output, the intake being located on the leading side of the lens, and the output underneath the lens, so that the rotation of the camera causes air to be redirected upward across the face of the lens.

29. A method for recording a stereoscopic image of a wide field of view, up to a complete sphere, including the steps of:

i. aligning at least two line scan devices within the field of view such that their optical axes are in the same plane, separated, approximately parallel, and pointed in the same direction;

ii. rotating said line scan devices simultaneously about an axis of rotation, the axis of rotation being approximately perpendicular to said plane and disposed equidistant to and between said line scan devices, said rotation being at the rate of at least 500 rpm;

iii. sampling the output of said line scan devices at least 1000 times each during said rotation, to produce scans from each sensor; and

iv. processing said scans so as to assemble a composite image having stereoscopic separation thoughout the image.

30. The method of claim 29, with the additional steps of placing duplicates of said line scan devices in rotated positions around said optical axis, and adjusting the timing of

the recording of the additional scans produced by said duplicates so that they appear interleaved with the scans produced by the original line scan sensors.

31. The method of claim 29, with the additional step of adjusting the convergence of the stereoscopic image by digital delays of the scans.

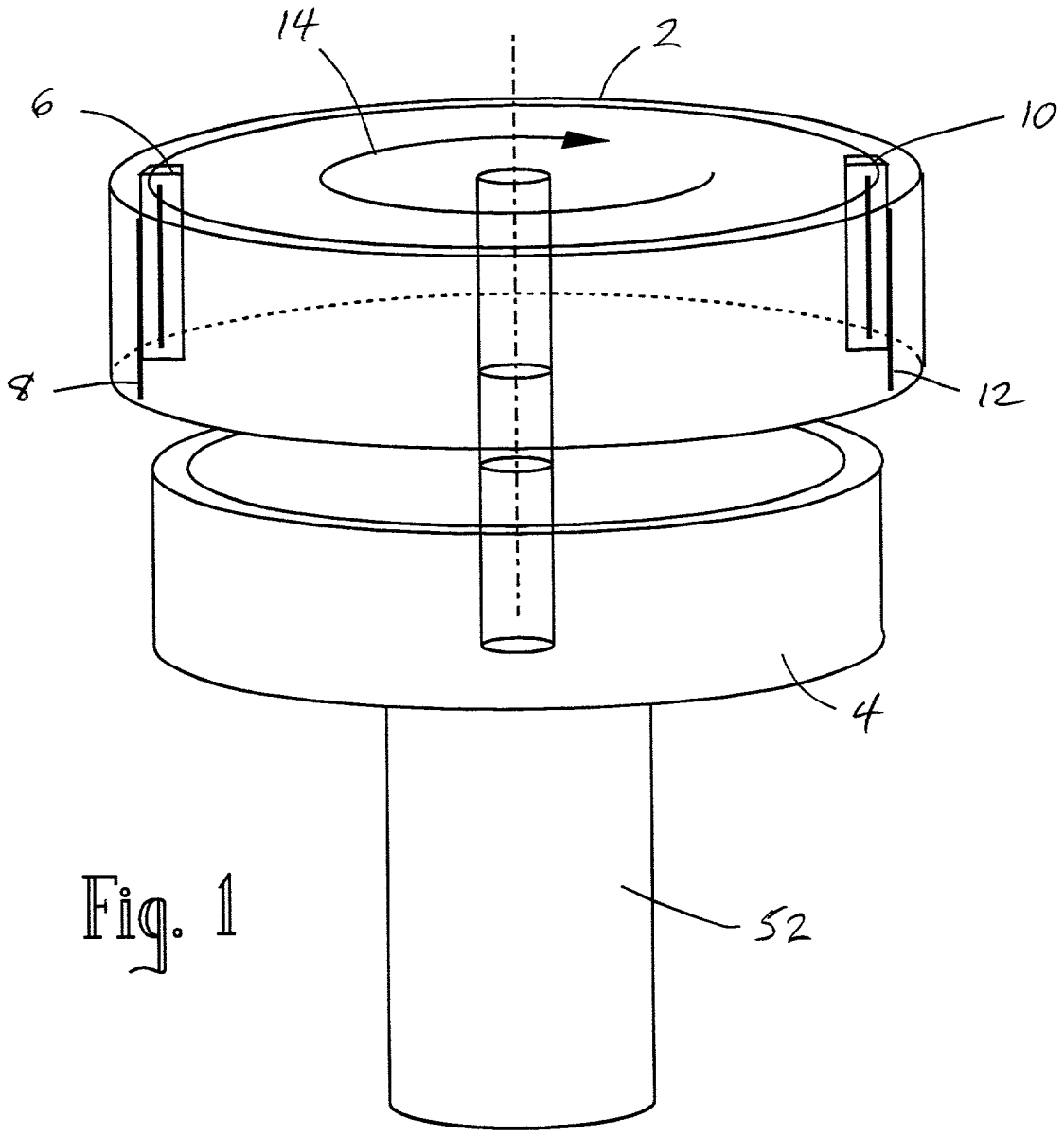
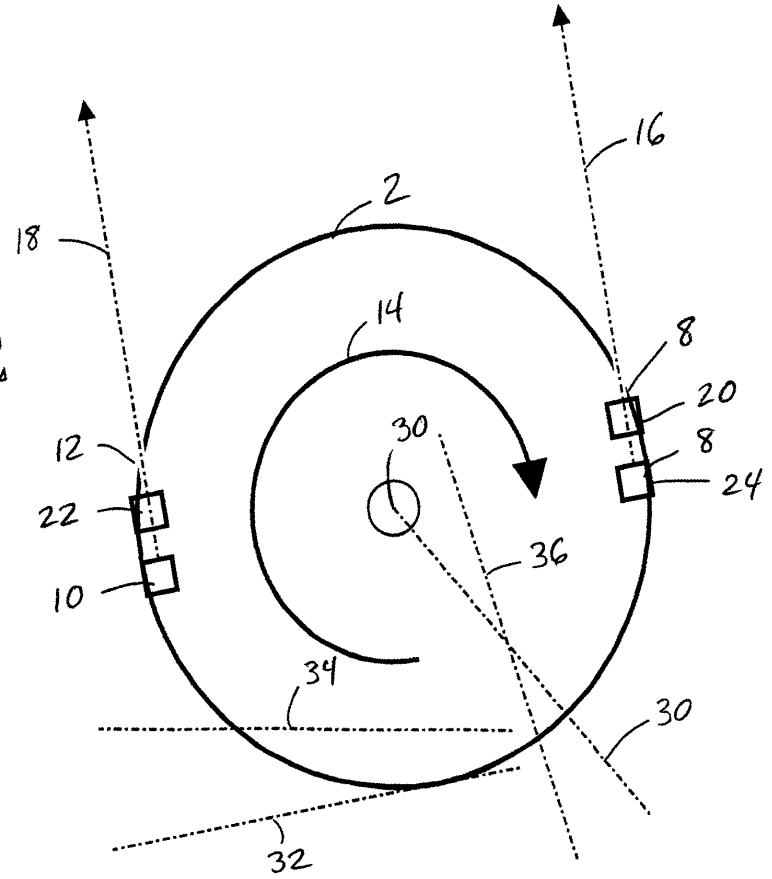


Fig. 1

Fig.2



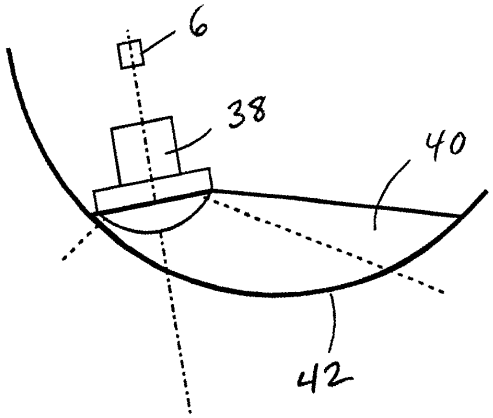


Fig.3

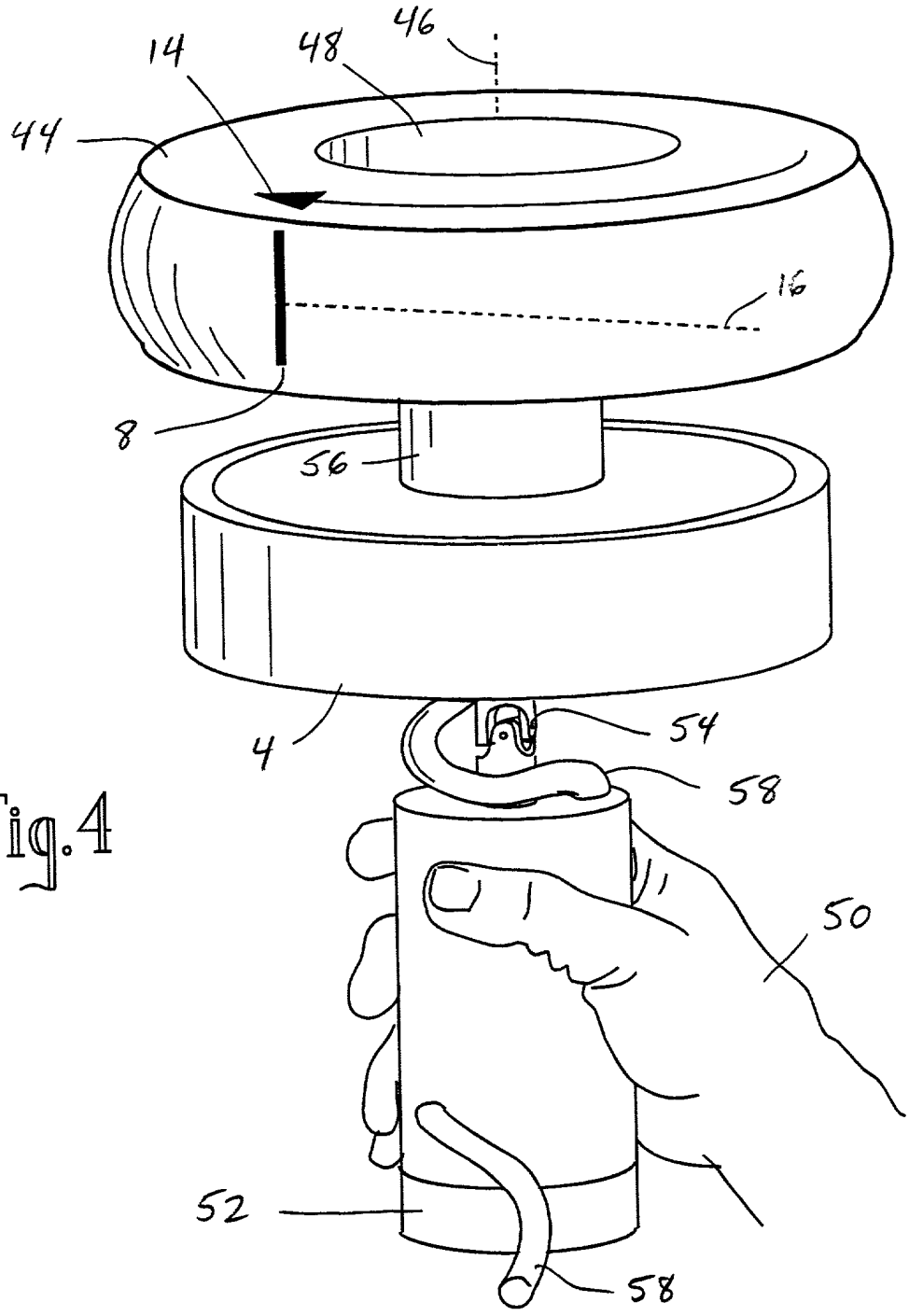


Fig.4

Patented Sep. 14, 2004

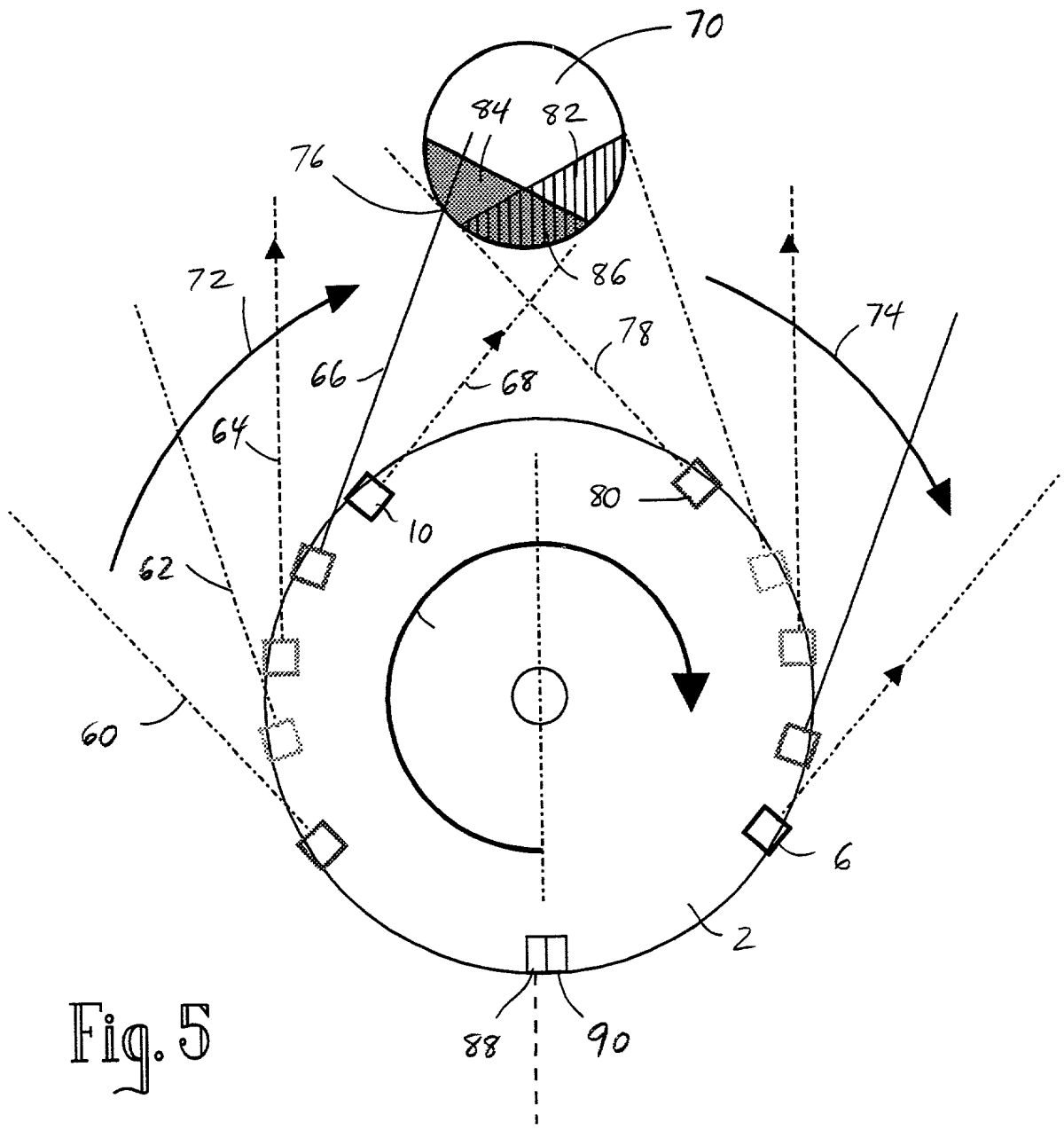


Fig. 5

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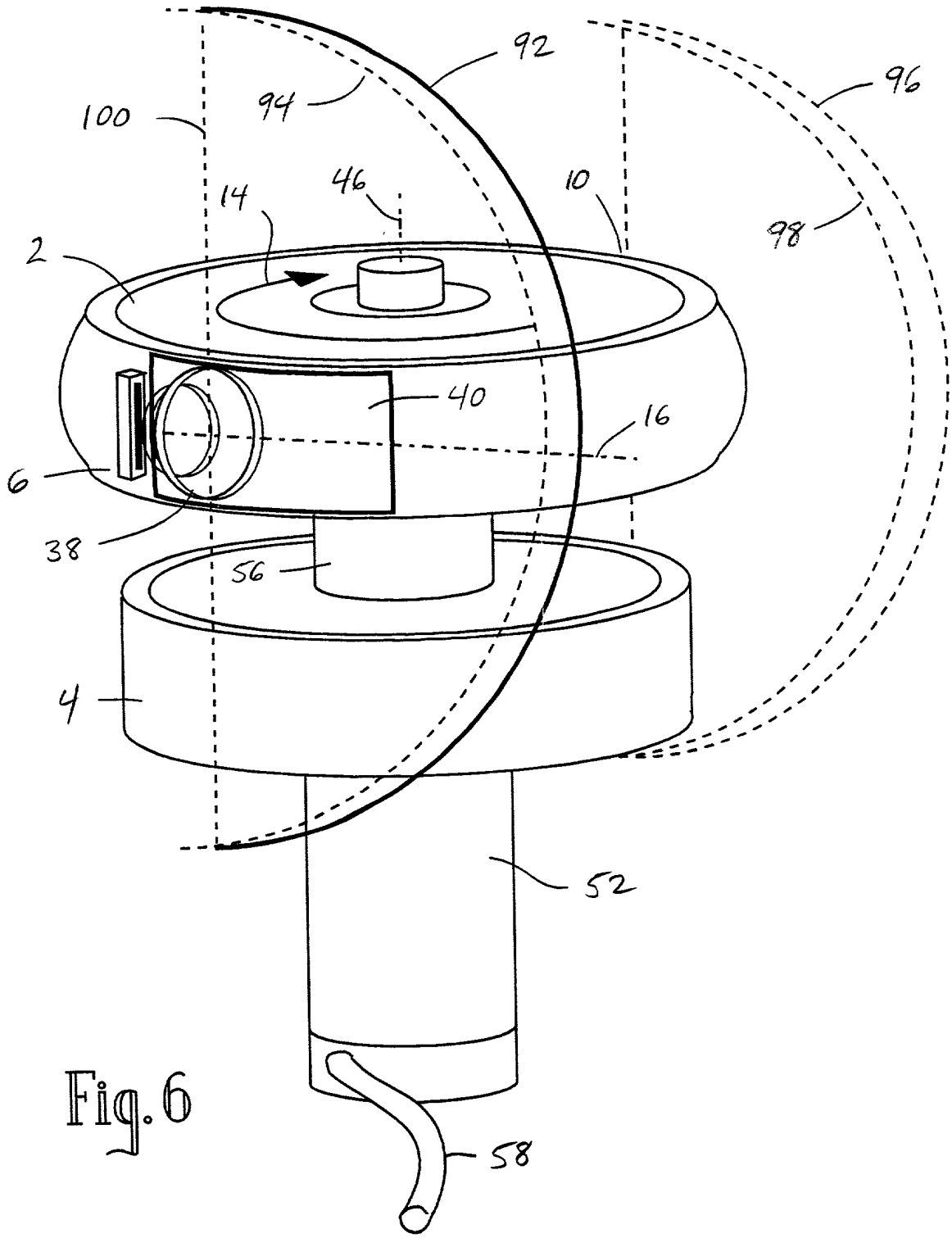

Fig. 6

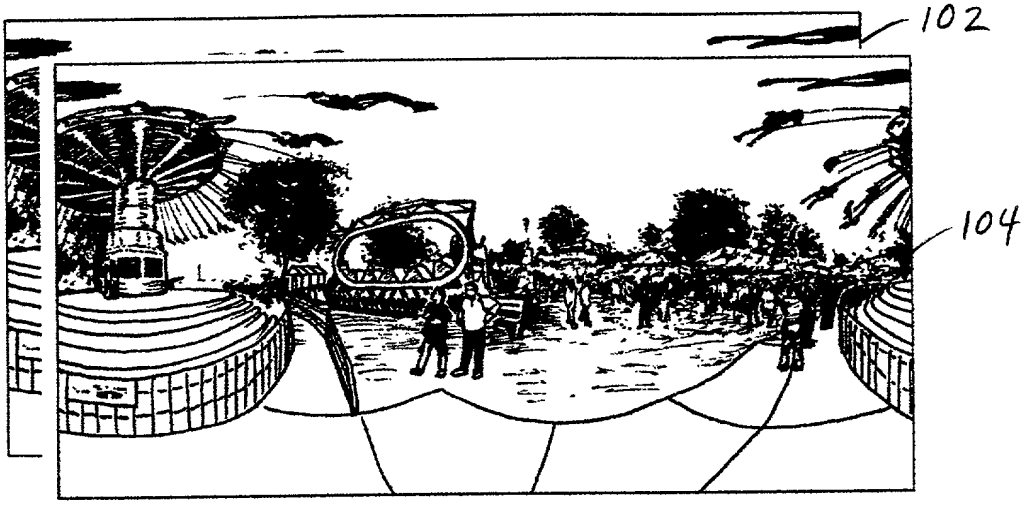

Fig. 7

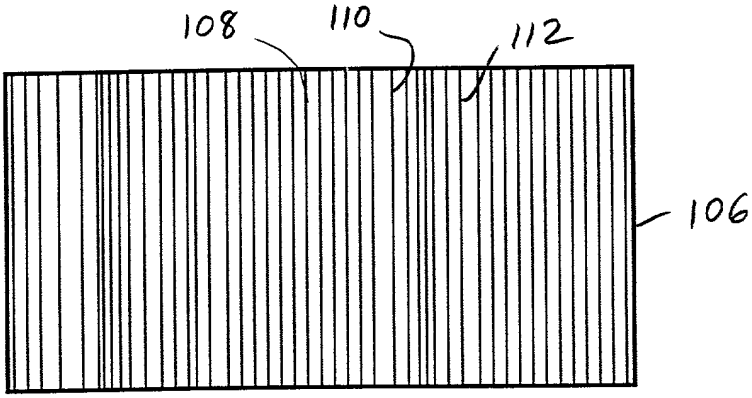

Fig. 8

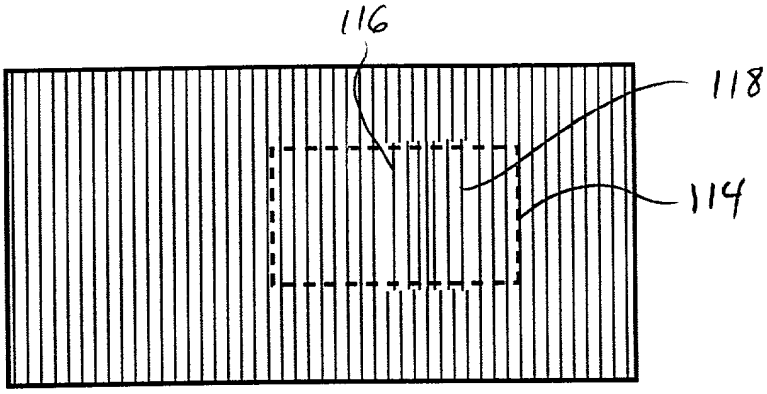

Fig. 9

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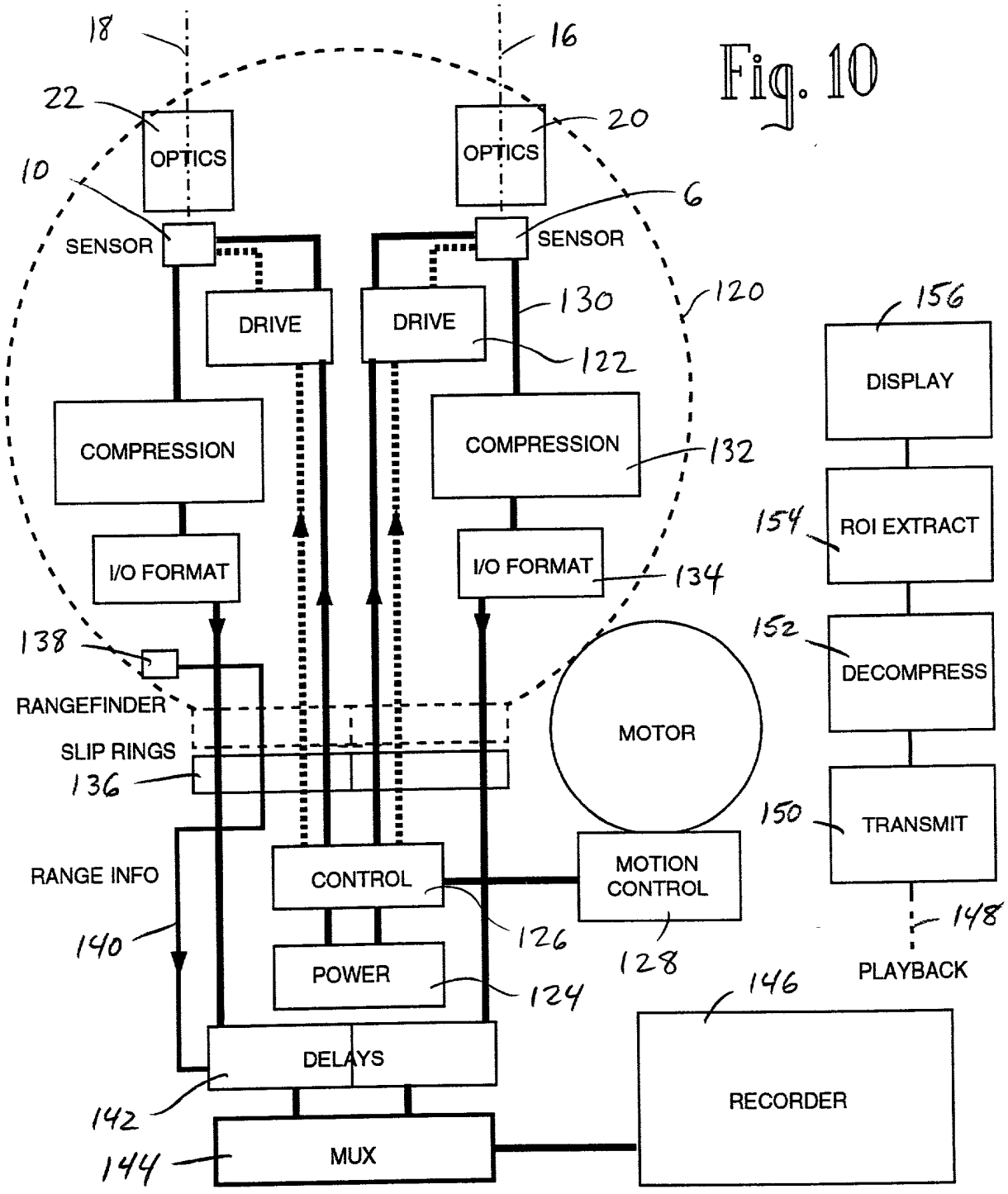
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COMPRESSION
132
154
ROI EXTRACT
I/O FORMAT
I/O FORMAT
134
152
DECOMPRESS
138
RANGEFINDER
MOTOR
SLIP RINGS
136
150
TRANSMIT
RANGE INFO
CONTROL
MOTION CONTROL
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148
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POWER
124
PLAYBACK
146
DELAYS
RECORDER
142
144
MUX

Fig. 10

patent application

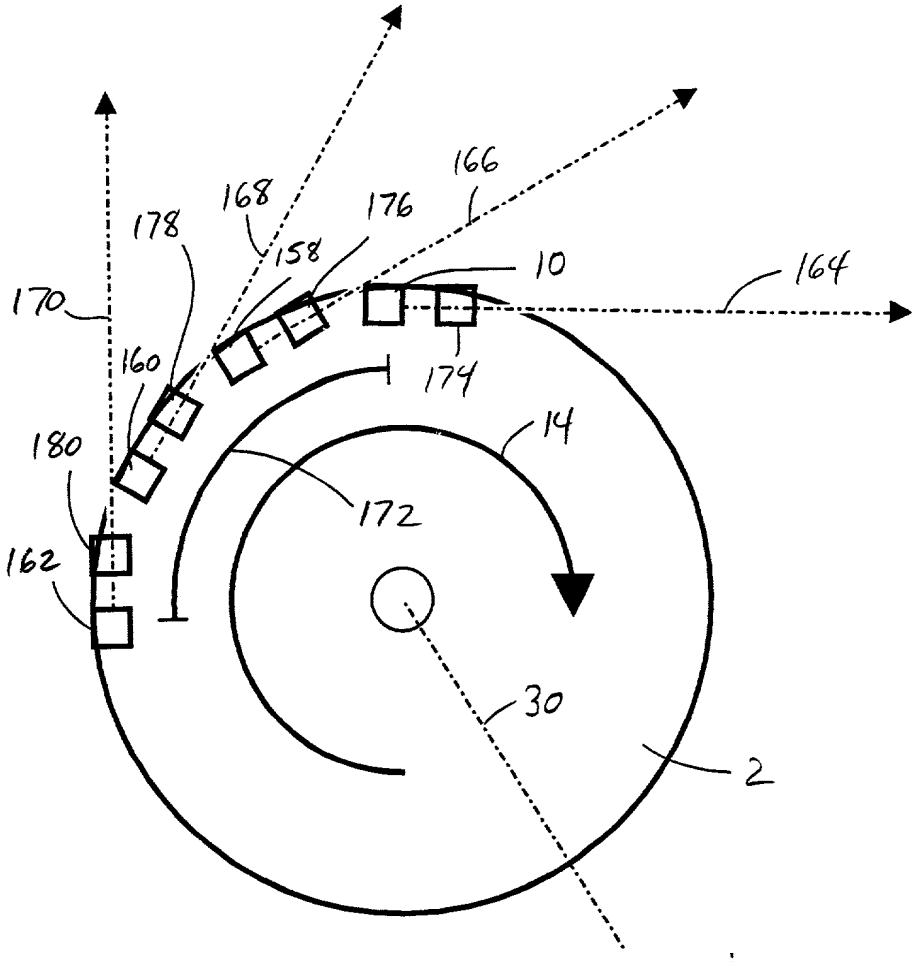
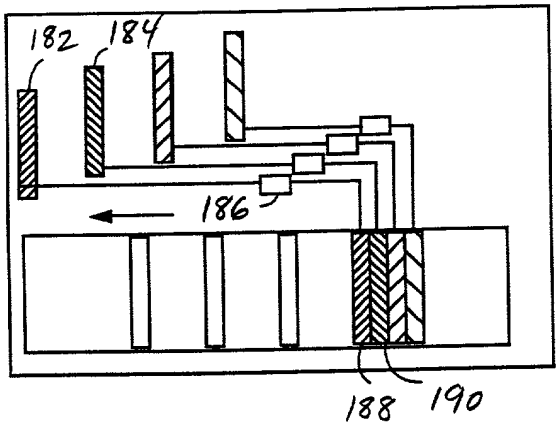


Fig. 11

Fig. 12



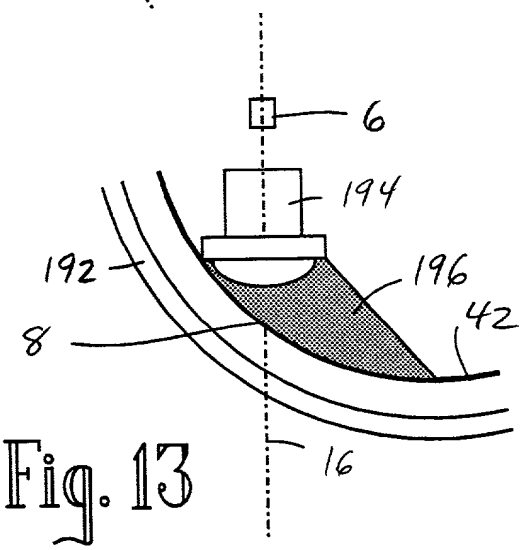


Fig. 13

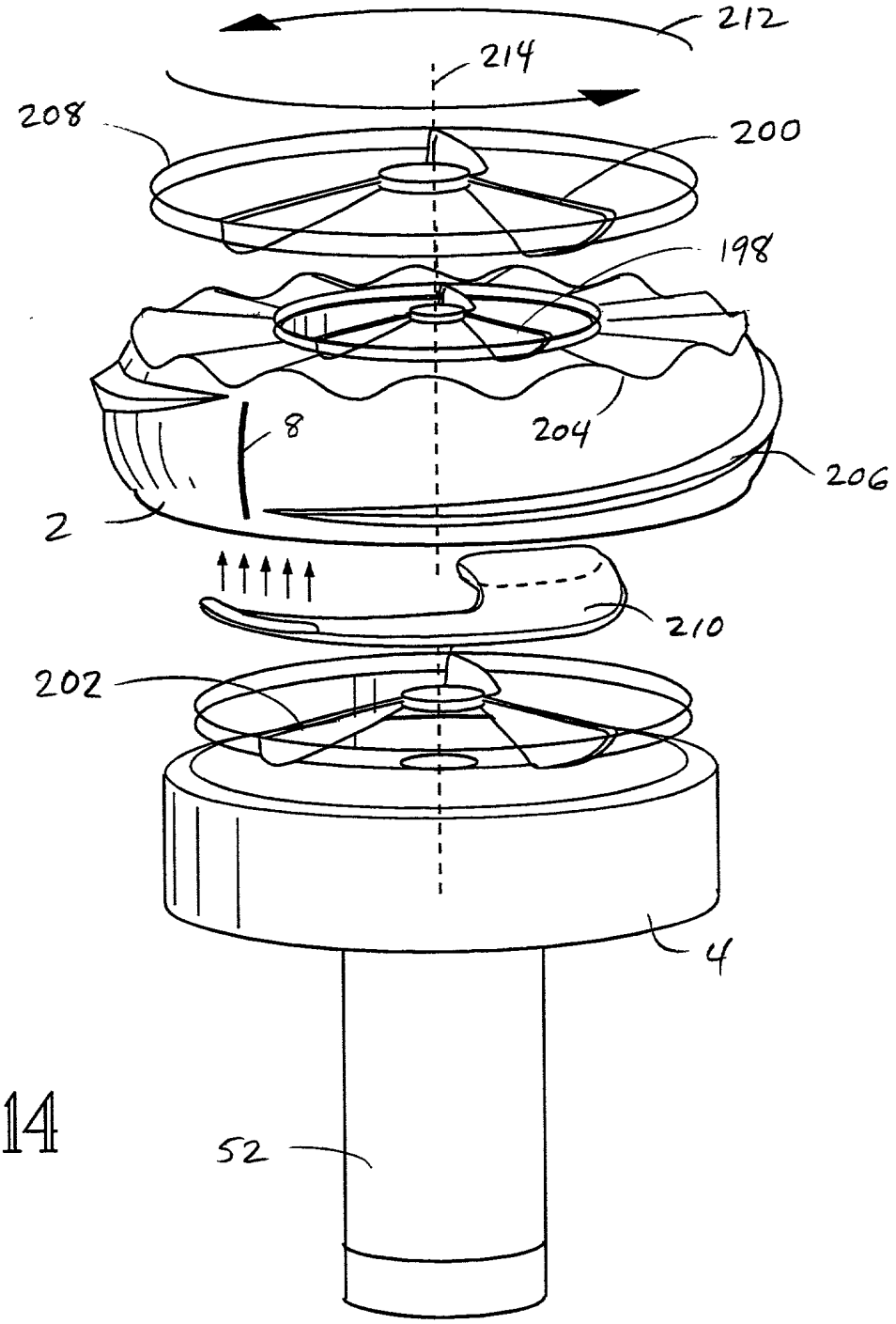
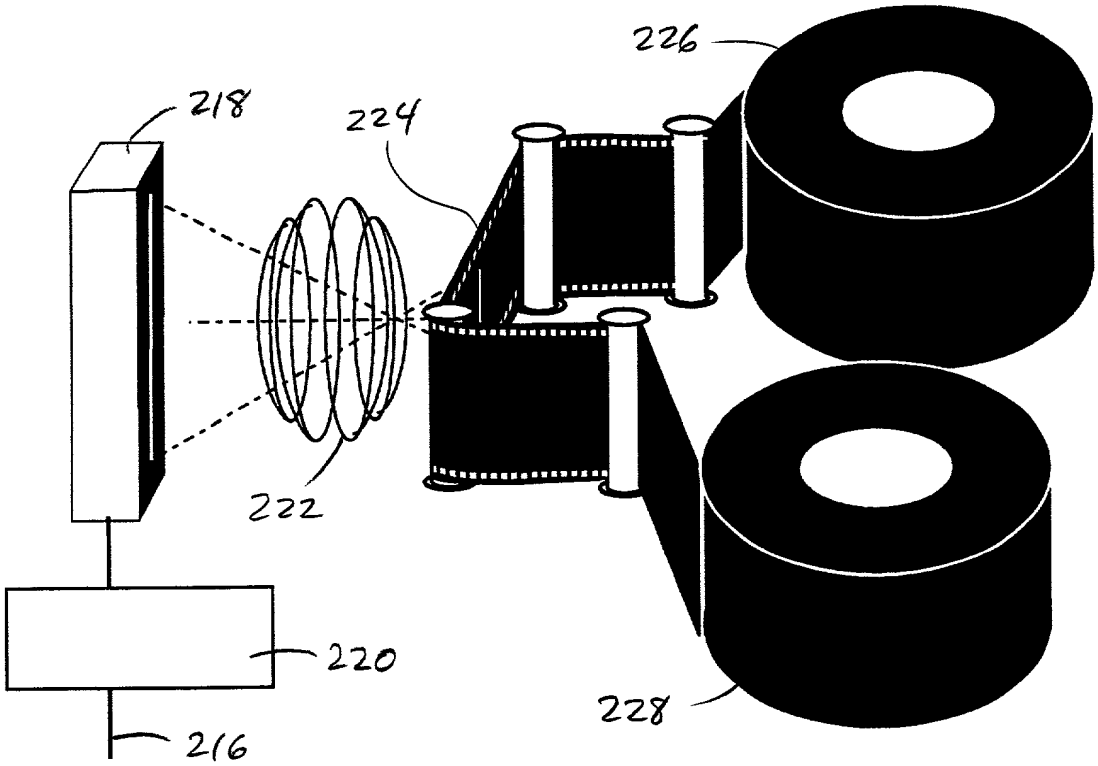


Fig. 14

EXHIBIT 1025

Fig. 15



Patented Dec. 4, 2001

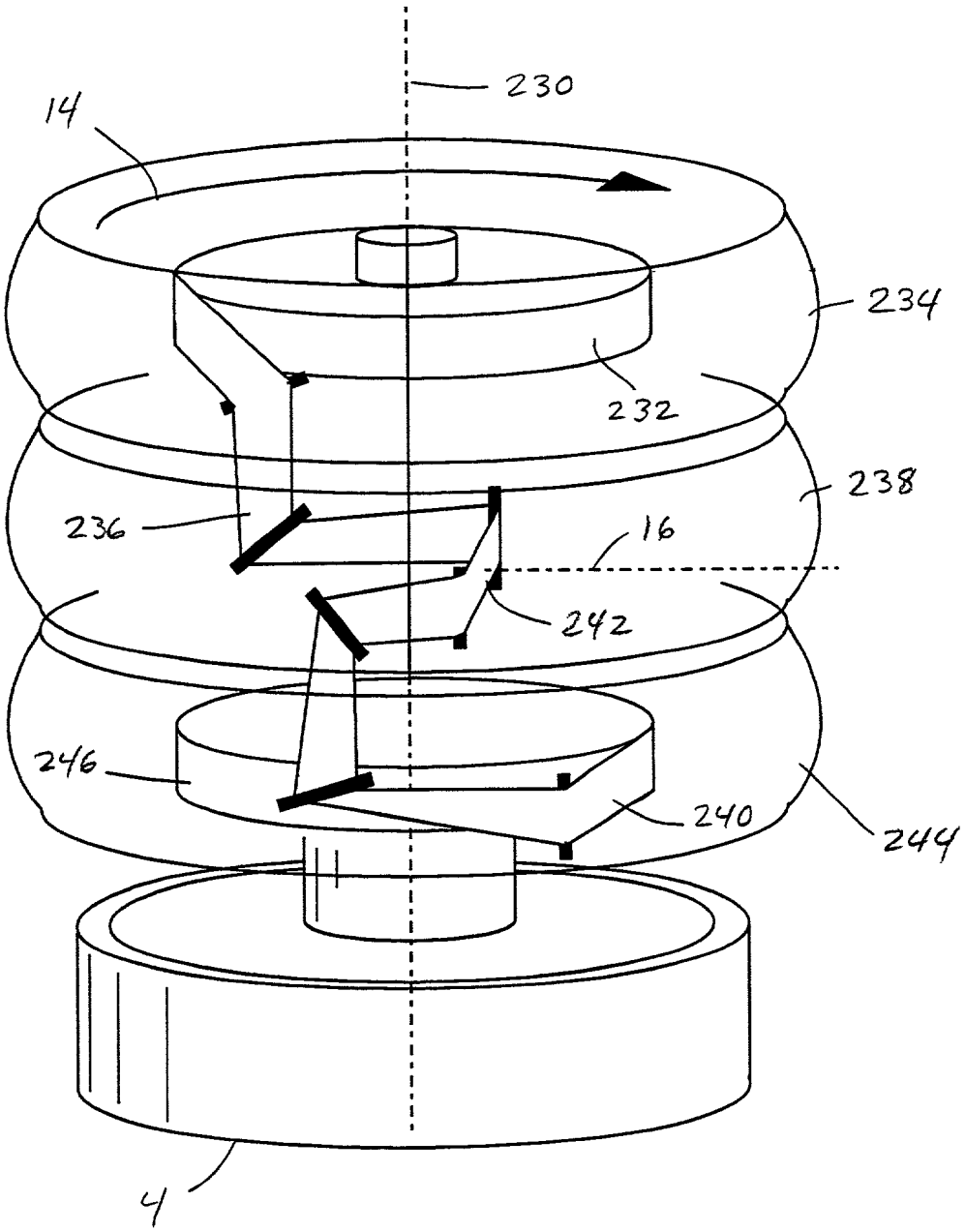


Fig. 16

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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☑ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	
First Named Inventor	McCUTCHEN
COMPLETE IF KNOWN	
Application Number	/
Filing Date	
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

ROTATING SCAN CAMERA

(Title of the Invention)

the specification of which
☑ is attached hereto
OR
☐ was filed on (MM/DD/YYYY) [ ] as United States Application Number or PCT International Application Number [ ] and was amended on (MM/DD/YYYY) [ ] (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)

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I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

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Name	Registration Number	Name	Registration Number

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Direct all correspondence to: ☐ Customer Number or Bar Code Label [ ] *OR* ☑ Correspondence address below

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City	PORTLAND	State	OR	ZIP	97202
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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle [if any])	Family Name or Surname
DAVID	McCUTCHEN

Inventor's Signature	David McCutchen					Date	2/17/00
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Post Office Address							
City	PORTLAND	State	OR	ZIP	97202	Country	USA

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